J-DARTS – An End-to-End Defence Planning Tool Set

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ABSTRACT

Long term defence planning is a complex undertaking involving many separate analytical steps and with non-trivial transitions from one step to the next. Many nations struggle with the challenge of establishing analytical rigour, structure and traceability in their defence planning processes. In this paper we will present a tool that has been developed not only to support defence planning, but which is also well suited to improve the structure of the process by requiring a formalisation of the individual steps of the analysis.

1. INTRODUCTION

J-DARTS (Joint Defence Planning Analysis and Requirements Tool Set) is an end-to-end tool for capability based planning. It has been under continuous development and enhancement at the NATO Consultation, Command and Control Agency (NC3A) since 2001 (one of the authors was responsible for its initial conception and implementation while employed at the Agency). It is now being used for NATO's Capability Requirements Review (CRR, formerly known as the DRR) and also at the Norwegian Defence Research Establishment (FFI) in support of Norwegian long term defence planning. NC3A maintains ownership and configuration control over J-DARTS, but the tool is available to NATO nations free of charge[1].

This paper will describe the overall structure of J-DARTS as well as its main components before summing up with some experiences of using the tool for real-world defence planning purposes. First, however, a quick overview of the planning processes for which it is designed to support is required.

The method for long term defence planning employed at FFI could loosely be called "capability based planning". It has certain similarities to NATO's approach in its CRR which is medium term and capability based planning across the spectrum of planning domains. A useful reference is the framework defined by SAS-025 "Handbook on Long Term Defence Planning", although there are some national adaptations compared with this.

The term capability is in this context synonymous with the ability to perform a certain task. In a capability based approach a capability taxonomy is used both to express requirements derived from scenarios and the abilities of units and platforms. This gives us flexibility in matching units and platforms to requirements and avoids zeroing in on specific solutions too early in the process.

Figure 1 illustrates the process flow and basic components of the method. There are two main lines of analysis. The bottom one, the force structure analysis, is a bottom-up process that aims to identify the capabilities and costs of the current and future force structure. The upper one, the scenario analysis, is a top-down process where we develop capability requirements, based on interpretations of the security environment, future challenges and national strategic goals.

[1] Some third-party licenses are required.

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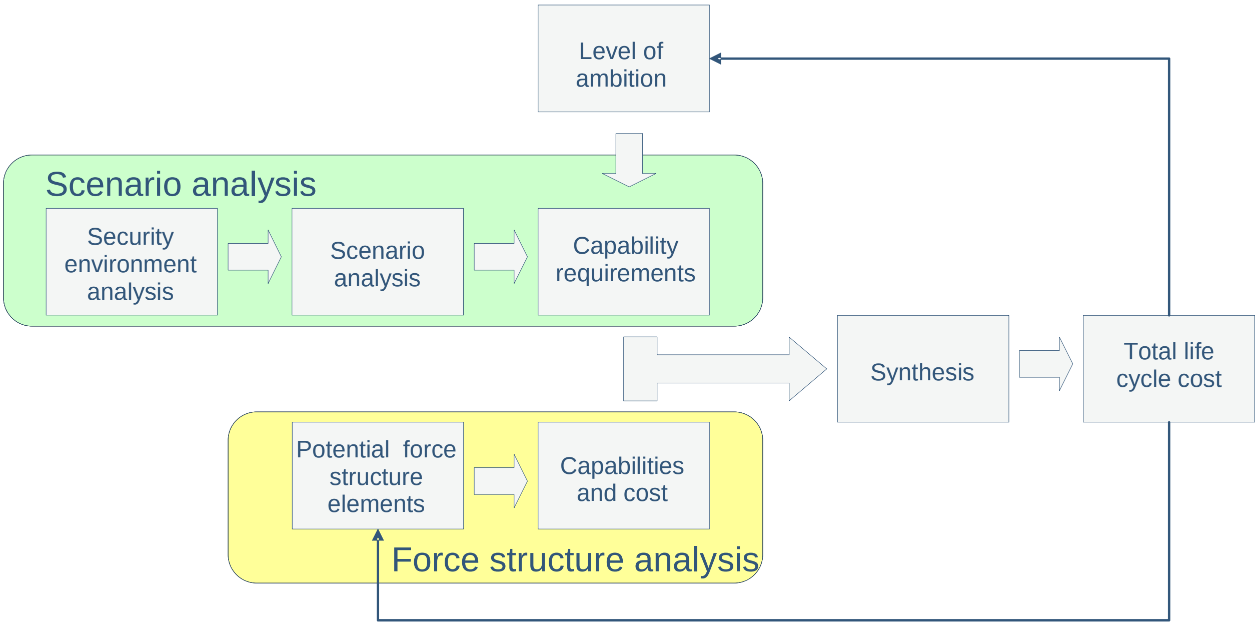


Figure 1: The long term planning process

J-DARTS is designed to support each of the steps depicted above and to facilitate the transition from one activity to the next. This is achieved through a number of multi-user applications all linked together and working off the databases in the so-called CDR, the Central Data Repository (an SQL Server group), as shown in Figure 2 below.

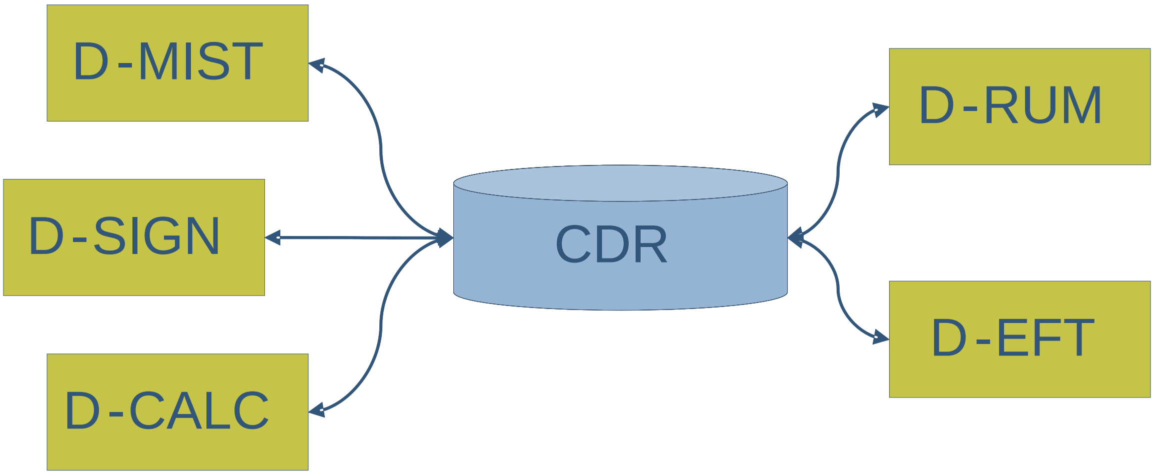


Figure 2: The J-DARTS application suite

The main applications in the J-DARTS suite are:

D-MIST (Defence Planning Mission Study Tool): An application that supports the mission analysis in Figure 1 above, including a hierarchical task decomposition and the creation, storage and visualisation of individual scenarios and scenario descriptions.

D-CALC (Defence Planning Capability Assignment Logic Calculator): This tool supports both the mission analysis through the development of (scenario independent) rules for capability assignment

and the scenario analysis by applying the those rules to specific scenarios.

D-SIGN (Defence Planning Scenario Information and Geographical Analysis tool): Utilising a GIS-interface, the role of D-SIGN is to specify the scenarios according to the framework given by the mission analysis and so provide parameter values to the capability assignment logic.

D-RUM (Defence Planning Requirements and Unit Matching Tool): On the one hand a repository for real-world units and their capabilities, on the other a tool for aggregation of the capability requirements stemming from (combinations of) the scenarios. D-RUM is also the controlling interface to D-EFT (see below) and a repository for the final force pool resulting from the running of D-EFT.

D-EFT (Defence Planning Extended Fulfilment Tool): A MIP-optimisation used to find the minimum set of forces (in terms of cost) that satisfies all capability requirements while adhering to a set of constraints on the use of units, force cohesion etc.

The sections below will give an overview of each of these activities and how J-DARTS has been designed to support them.

2. D-MIST – MISSION TYPES, SCENARIOS AND TASK DECOMPOSITION

The derivation of capability requirements is based on an analysis of the national security situation, future challenges and national strategy. What we aim for is a set of mission types which spans – to the greatest extent possible – the space of potential future challenges to national security. The mission types are generic scenarios, which mean that they do not contain specifics with regard to parameters such as time, place or opponent. Examples on mission types could be “Collective Defence” or “Crisis Containment”. To develop a complete set of mission types we have take into account both national and international challenges.

The mission types are not specific enough to be used for the derivation of meaningful capability requirements. It is therefore necessary to develop concrete situations where geography, actors and time lines are defined. These are called scenarios and are detailed examples of the mission types described above.

The scenario analysis consists mainly of a decomposition of each mission type into objectives, tasks and subtasks, as shown in Figure 3. The subtasks are then analysed to determine the capability requirements for each of them.

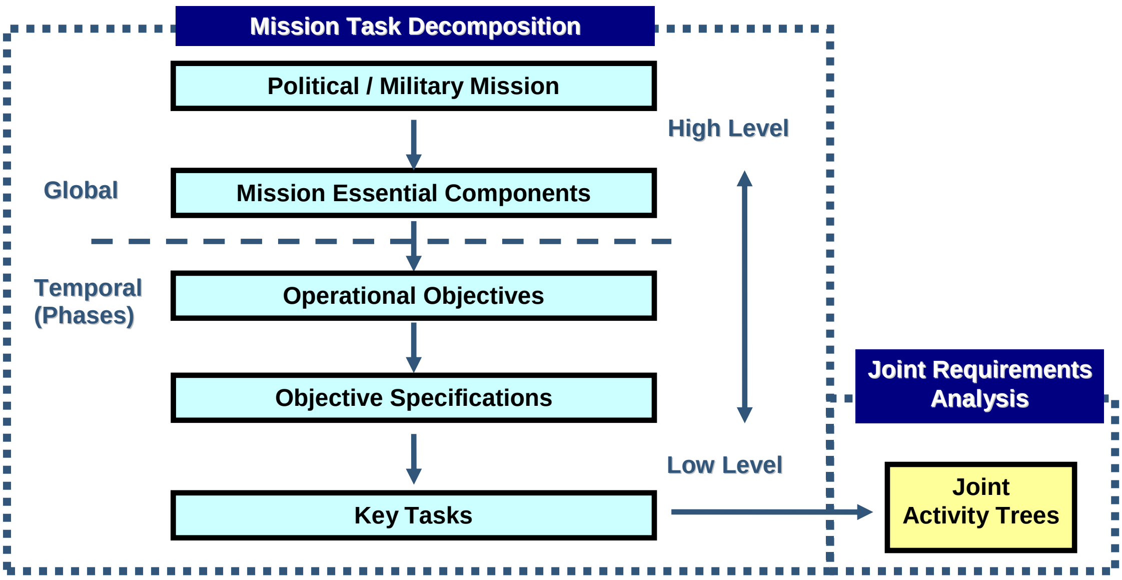


Figure 3: Mission Task Decomposition

The creation and analysis of mission types, the task decomposition and a textual definition of the individual scenarios are facilitated by the tool D-MIST. As shown in Figure 4, the D-MIST interface contains two main elements. On the right hand side, the mission task decomposition of the various mission types can be specified according to the structure given in Figure 3. On the left hand side, a textual description of the different scenarios defined for each of the mission types is displayed as an embedded and editable Word document. D-MIST also allows the creation and deletion of mission types and scenarios.

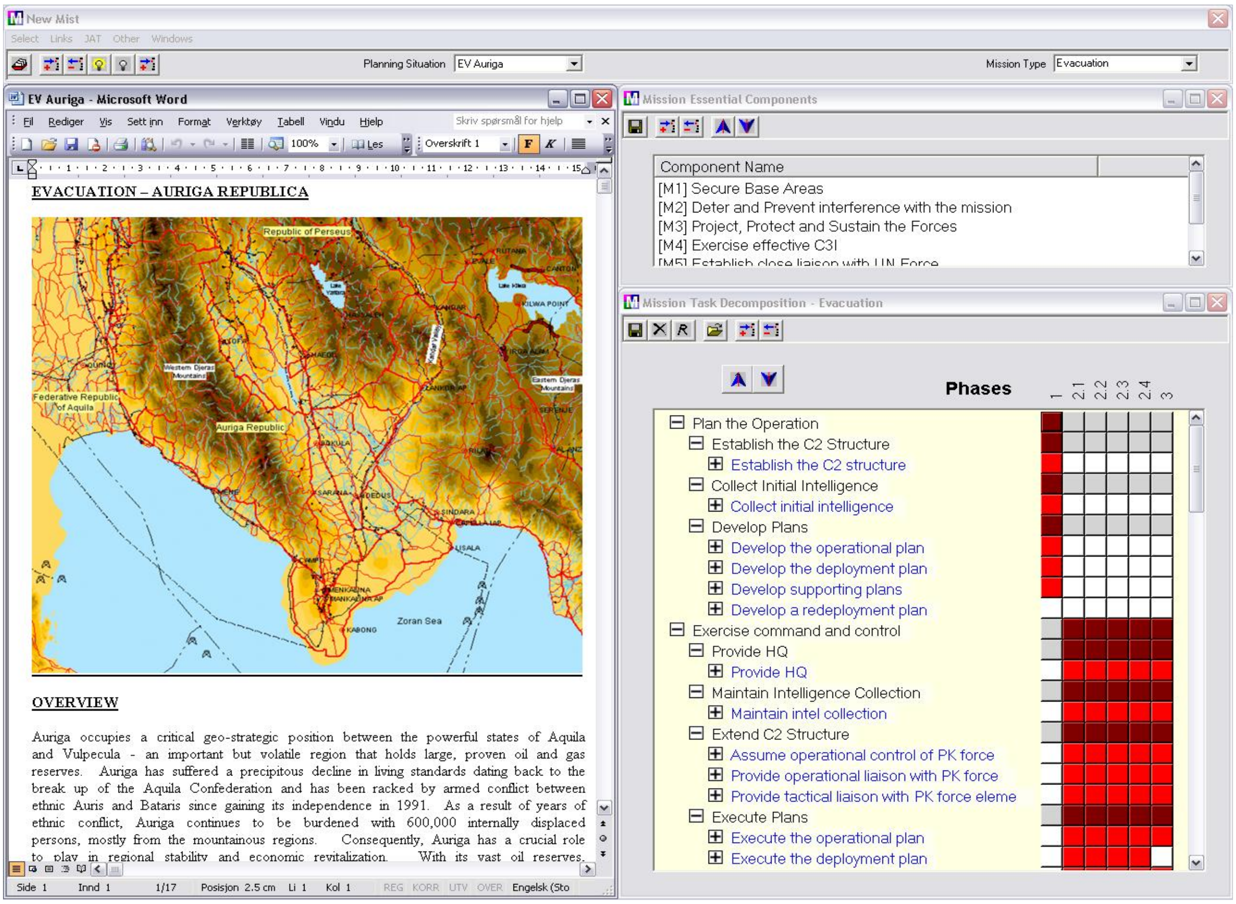


Figure 4: D-MIST

The output from D-MIST, forming the necessary starting point for the next step in the overall analysis, is the list of key tasks for each of the mission types. The key tasks are the lowest level in the task hierarchy and will typically imply challenges at the low operational or high tactical level. The analysis of and definition of "solutions" – in terms of capability requirements – for these key tasks are implemented through D-CALC.

3. D-CALC – CAPABILITY REQUIREMENTS ANALYSIS

The Joint Activity Trees (JATs) – see Figure 3 – are not formally part of the Mission Task Decomposition, but they *are* part of the mission analysis. A JAT is a generic solution to the problem posed by a Key Task (KT) in the shape of a recipe or Capability Assignment Logic (CAL). There are potentially more than one solution to a Key Task and there may therefore be more than one JAT attached to a KT. Which JATs that end up being selected depend on the specifics of a given scenario. The CALs, which are mission type

specific, will produce quantitative capability requirements for JATs (and hence KTs), the size of which depends on planning situation specific parameter values. This is implemented in the application D-CALC, shown in Figure 5.

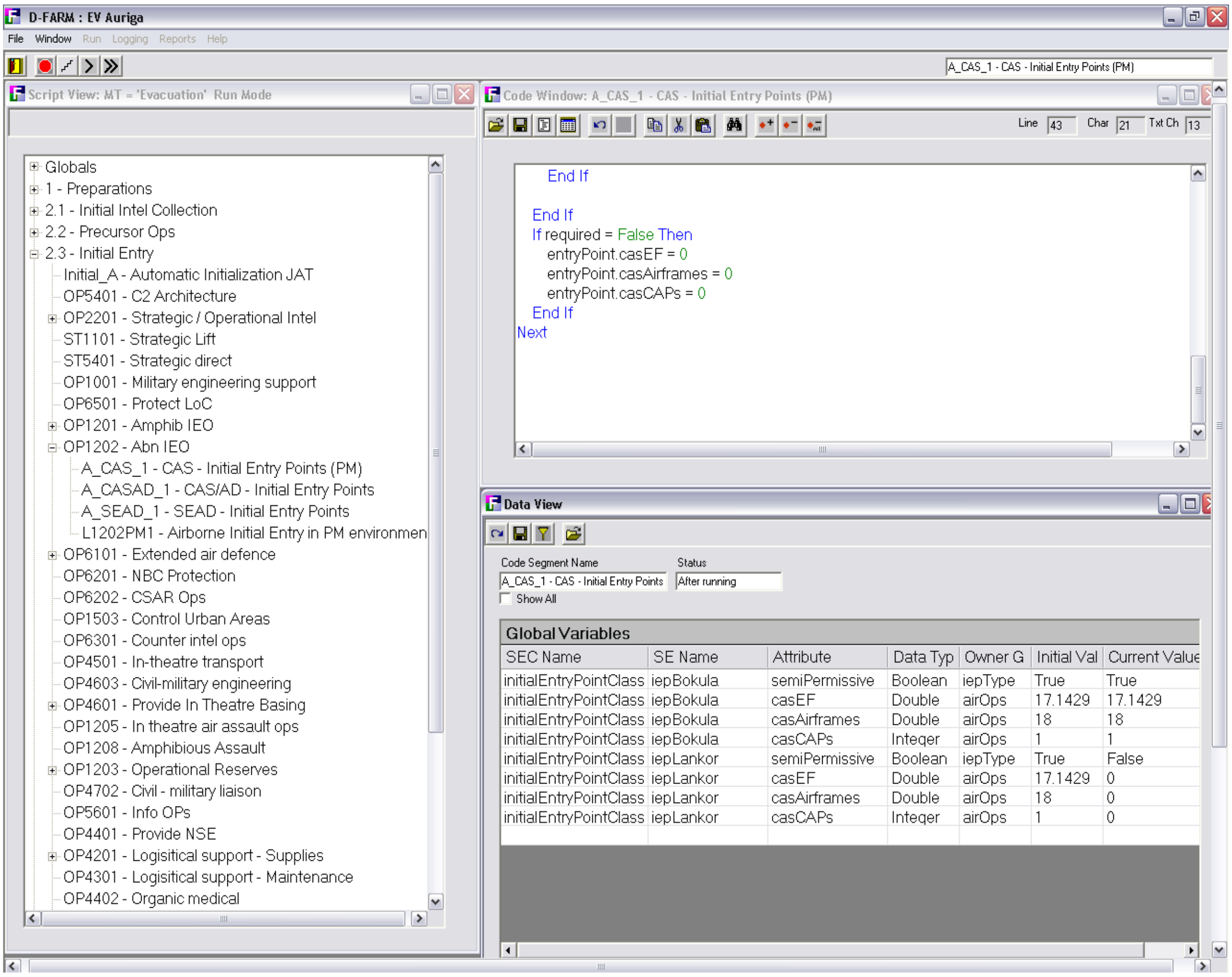


Figure 5: D-CALC

There are two main elements in D-CALC. The execution script, displayed in the left hand window pane in Figure 5, is a script that mandates the sequence in which the JATs should be executed for a given mission type. Furthermore, the script links each of the JATs with one or more code segments, which contains the actual code to be executed for a given JAT.

The code segments, an example is partly visible in the upper right hand corner of the figure, are implementations of the CALs and generate the capability requirements for a specific JAT. These are relatively simple rules, defined in a Basic-like language, and could be based on doctrine, results from simulation models, historical experience or military judgment. There are also special code segments that deal with the aggregation of capability requirements across space and time (i.e. across geography and phases), since the total capability requirements of a scenario are not simply the sum of all the low-level requirements.

When all the necessary code segments have been defined for all of the JATs of a given mission type a scenario of that type can be "run" in order to generate the capability requirements for that scenario. It should be noted that the scripts and the code segments are specific to the mission types and not to the

scenarios. The parameter values used by the code segments are, however, scenario specific and necessary to calculate the scenario specific capability requirements. These parameter values are specified through the D-SIGN application.

4. D-SIGN – SCENARIO SPECIFICATION

D-SIGN, shown in Figure 6, is a map-based tool (a plug-in to the commercial GIS tool Maria[2]) that allows the specification of individual scenarios. The mission task decomposition at the mission type level identifies *what* needs to be done (i.e. the required capabilities), the scenario definition specifies the scenario parameters needed to calculate – in D-CALC – *how much* is needed (i.e. the required capacities). Typical parameters could come from the specification of timelines, threat, LOCs, bases etc.

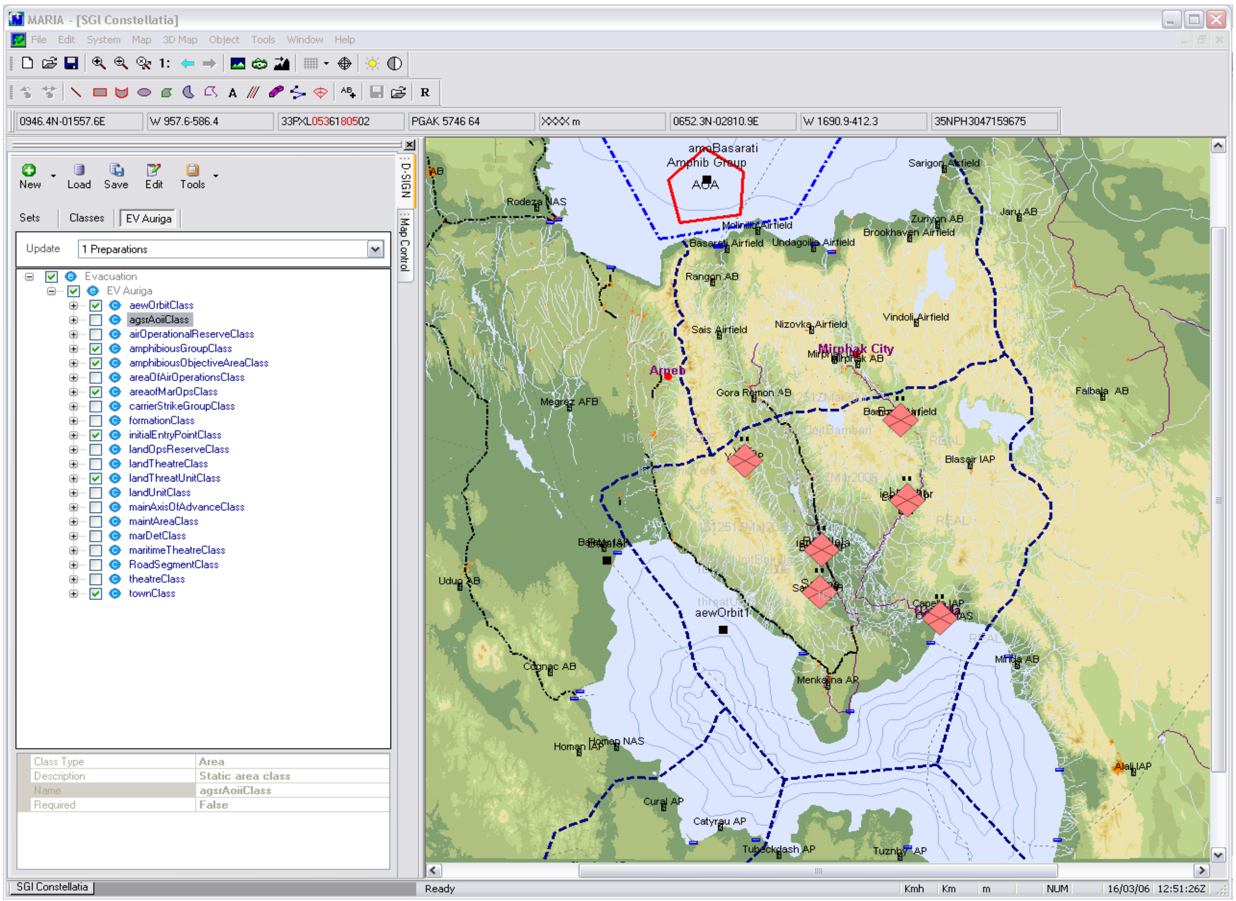


Figure 6: D-SIGN

Apart from supplying the parameter values needed by D-CALC, D-SIGN is also useful for documenting and visualising both the scenario definition and the results of the scenario analysis. The capability requirements resulting from running D-CALC can be accessed through D-SIGN and automatically associated with specific scenario elements.

2 http://www.teleplanglobe.com/index.php/products/maria

5. D-RUM – FORCE STRUCTURE ANALYSIS

The previous sections have all been about requirements. In order to establish a long-term plan, we also need to consider how these requirements shall be met in terms of a real-world force structure. D-RUM is a tool that facilitates this. There are three main elements constituting D-RUM.

First, D-RUM collects all capability requirements from all scenarios and combines them into so called benchmarks in accordance with a specified level of ambition. The level of ambition is a logical algorithm that defines the mission types and scenarios that should be allowed to generate capability requirements, and the allowed concurrency of the same. Each benchmark is a set of requirements from concurrent scenarios and thus represents a set of challenges that the future force structure ideally should be able to handle.

Second, D-RUM provides the interface to the real-world force structure elements (widely defined; not only combat units, but also logistics, air bases etc.) These are stored with administrative data such as unit name, location, readiness, its place in the force structure hierarchy and also cost data, i.e. the life cycle cost of the unit and the required supporting elements directly associated with the unit. Furthermore, data regarding the use of a unit may also be specified, for instance which scenarios it may or may not be used in, whether it can be split and used in more than one scenario, if it must always deploy with another unit and so on. Most importantly, however, D-RUM allows the specification of a unit's capabilities and capacities, as shown in Figure 7.

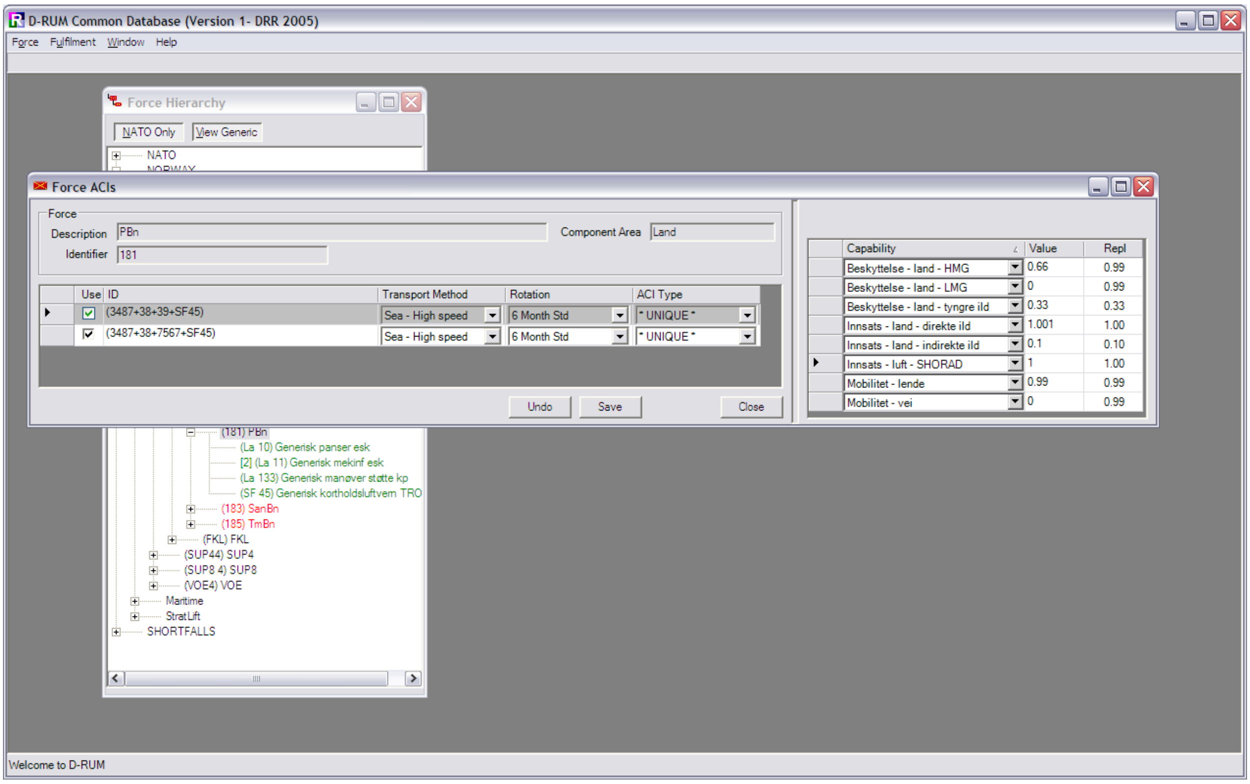


Figure 7: Unit capabilities

Any given unit will have one or more capability, using the same capability definitions as for the scenario analysis. The unit's *effectiveness* – i.e. its capacity – for a selected capability is given relative to the performance of a reference unit. Such reference units, or yardsticks, are defined for each capability. This approach allows the exploration of different solutions and trade-offs between platforms and units with overlapping sets of capabilities against a given set of capability requirements.

Third, D-RUM provides an interface to D-EFT (see below) in order to control the optimisation that generates the force structure and to inspect the result. It is also possible to see how the units have been used in the different benchmarks and scenarios, as shown in Figure 8.

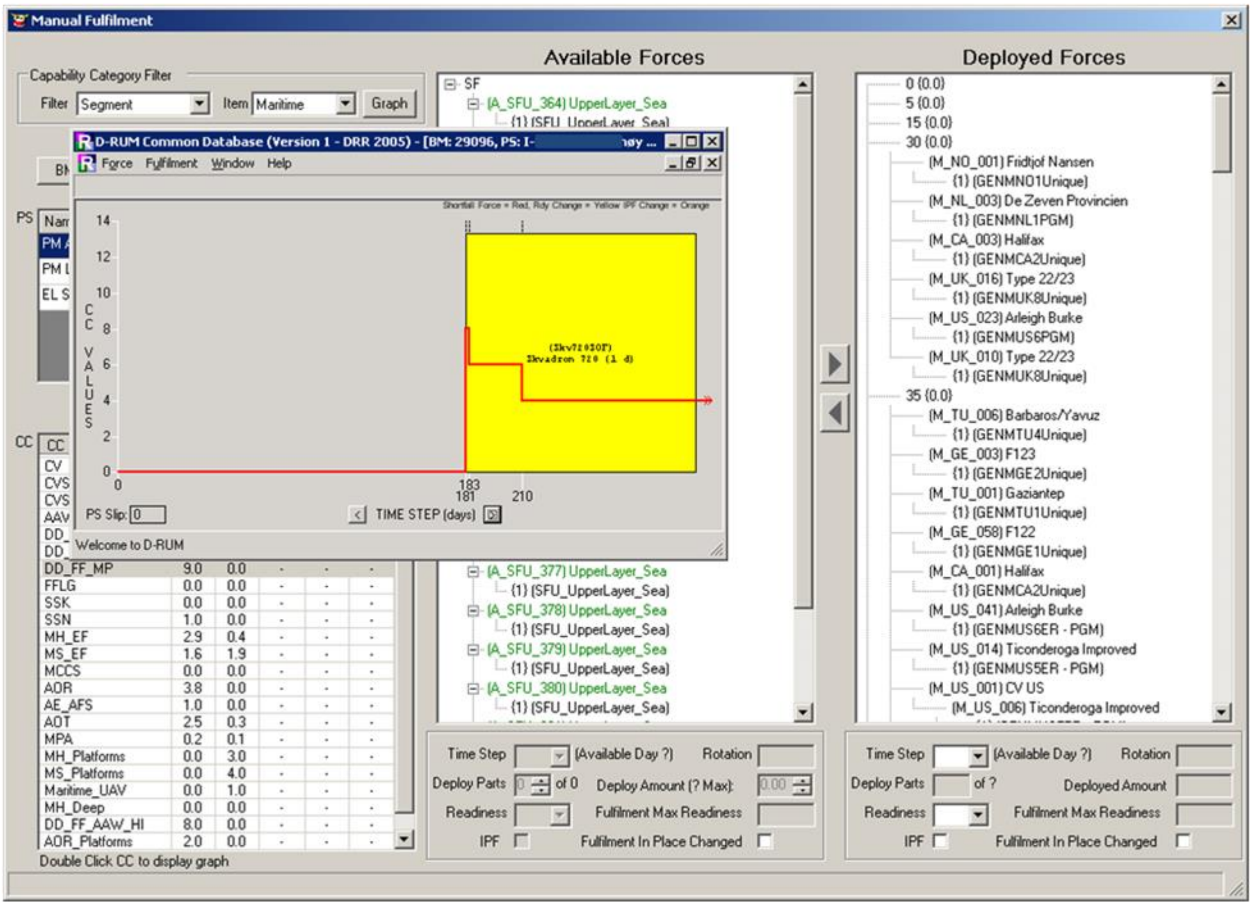


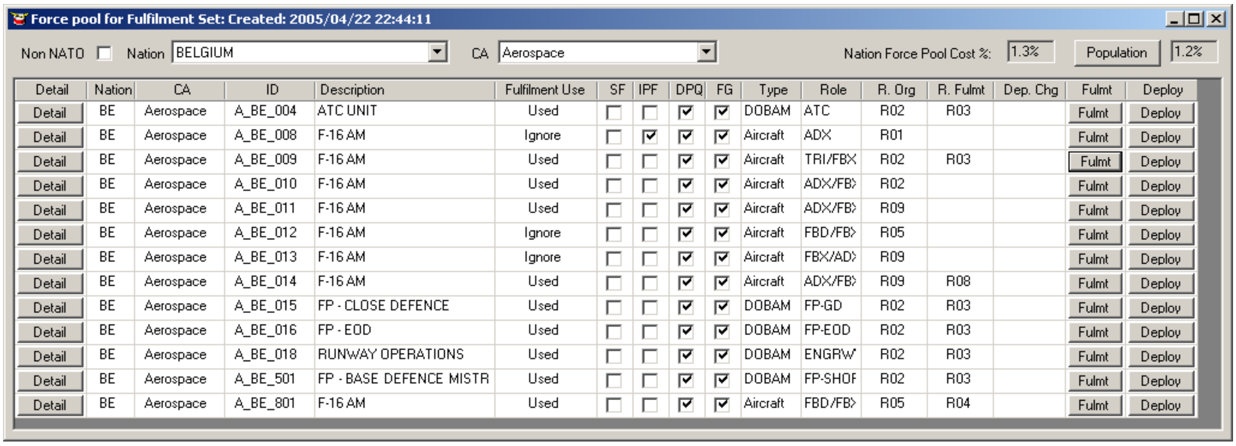
Figure 8: D-RUM, allocation of units against requirements

6. D-EFT – FORCE STRUCTURING

The job of collecting all the loose threads and come up with what is the ultimate goal of the planning process – a suggested future force structure – is handled by D-EFT. In practise this is done as a Mixed Integer Programme (MIP) employing the CPLEX[3] algorithm. This is a mathematical and deterministic algorithm which – given inputs like costs, capabilities, level of ambition and capability requirements – matches forces to benchmarks and scenarios so that all capability requirements are fulfilled at the lowest possible cost.

The most powerful application of the method is to use it in a constructive manner. If we take as a starting point a great number of potential structural elements – representing both legacy units, potential acquisitions and radical new technologies – D-EFT will construct a force structure, as shown in Figure 9, which represent the most cost effective fulfilment of the capability requirements posed by the scenario analysis and the selected level of ambition.

[3] http://www-01.ibm.com/software/integration/optimization/cplex-dev-bundles/



Force pool for Fulfilment Set: Created: 2005/04/22 22:44:11

Non NATO ☐ Nation BELGIUM CA Aerospace Nation Force Pool Cost %: 1.3% Population 1.2%

Detail	Nation	CA	ID	Description	Fulfilment Use	SF	IPF	DPQ	FG	Type	Role	R. Org	R. Fulmt	Dep. Chg	Fulmt	Deploy
Detail	BE	Aerospace	A_BE_004	ATC UNIT	Used	☐	☐	☑	☑	DOBAM	ATC	R02	R03		Fulmt	Deploy
Detail	BE	Aerospace	A_BE_008	F-16 AM	Ignore	☐	☑	☑	☑	Aircraft	ADX	R01			Fulmt	Deploy
Detail	BE	Aerospace	A_BE_009	F-16 AM	Used	☐	☐	☑	☑	Aircraft	TRI/FBX	R02	R03		Fulmt	Deploy
Detail	BE	Aerospace	A_BE_010	F-16 AM	Used	☐	☐	☑	☑	Aircraft	ADX/FB>	R02			Fulmt	Deploy
Detail	BE	Aerospace	A_BE_011	F-16 AM	Used	☐	☐	☑	☑	Aircraft	ADX/FB>	R09			Fulmt	Deploy
Detail	BE	Aerospace	A_BE_012	F-16 AM	Ignore	☐	☐	☑	☑	Aircraft	FBD/FB>	R05			Fulmt	Deploy
Detail	BE	Aerospace	A_BE_013	F-16 AM	Ignore	☐	☐	☑	☑	Aircraft	FBX/AD>	R09			Fulmt	Deploy
Detail	BE	Aerospace	A_BE_014	F-16 AM	Used	☐	☐	☑	☑	Aircraft	ADX/FB>	R09	R08		Fulmt	Deploy
Detail	BE	Aerospace	A_BE_015	FP - CLOSE DEFENCE	Used	☐	☐	☑	☑	DOBAM	FP-GD	R02	R03		Fulmt	Deploy
Detail	BE	Aerospace	A_BE_016	FP - EOD	Used	☐	☐	☑	☑	DOBAM	FP-EOD	R02	R03		Fulmt	Deploy
Detail	BE	Aerospace	A_BE_018	RUNWAY OPERATIONS	Used	☐	☐	☑	☑	DOBAM	ENGRW'	R02	R03		Fulmt	Deploy
Detail	BE	Aerospace	A_BE_501	FP - BASE DEFENCE MISTR	Used	☐	☐	☑	☑	DOBAM	FP-SHOF	R02	R03		Fulmt	Deploy
Detail	BE	Aerospace	A_BE_801	F-16 AM	Used	☐	☐	☑	☑	Aircraft	FBD/FB>	R05	R04		Fulmt	Deploy

Figure 9: Output from D-EFT – the force structure

Another way to use J-DARTS is to let D-EFT evaluate the capabilities of an already existing or proposed force structure. By matching the capabilities of the force structure to the capability requirements derived from the scenarios and level of ambition, the method gives an explicit quantification of what the structure is lacking with regard capabilities, capacities and readiness as well as surpluses with respect to the same. Gaps identified can then either be rectified or a choice can be made to accept the – again explicit and quantifiable – risks associated with leaving gaps unfulfilled.

Running D-EFT will of course not result in an optimal – or acceptable – force structure the first time the button is pushed. There will invariably be inputs and assumptions that need to be adjusted both in order to correct mistakes, but also, for instance, to incorporate constraints on the use of forces. The scenario analysis and the capability and cost evaluations are both, at least at some level, based on judgement and uncertainties and inaccuracies will play a part. The answers can therefore not be represented as any kind of objective, scientific 'truth'. The strength of the analysis is, on the other hand, that the audit trail is very clear and that the effect of all assumptions can be quantified and tested.

7. USING J-DARTS

A total force structure will not be fully defined after the first run-through in J-DARTS. The path from the current structure to the target structure must be defined, total cost for both the force and support structure must be analysed, the risk associated with the acquisition of new, untested technologies evaluated and specific constraints and guidelines may need to be incorporated. A number of iterations will need to take place where it may well turn out that the level of ambition must be adjusted if, for instance, the total cost of realising the original ambition level turns out to be unrealistically high.

In this way, we may converge towards a defence structure which is acceptable with policy makers, but which is also in a certain sense internally consistent and for which a clear audit trail from the level of policy and security environment assessment down to the specific force structure elements is available.

J-DARTS and the methodology it is the implementation of have been used at FFI in support of Norwegian long term defence planning since the so-called Defence Study 2007. A full set of scenarios has been developed and analysed and J-DARTS have been run on a number of occasions to provide a basis for the force structuring process. It is now one of the main tools underpinning the new continuous planning process currently being implemented by the Norwegian MoD (as opposed to the 4-year cyclical process used previously). J-DARTS is also still in use in NATO in support of the CRR.

J-DARTS is a complex suite of tools and it requires a considerable investment of time and manpower before it can be used for serious analysis. For nations with limited resources in the area of defence research it can make more sense to employ a simpler spreadsheet based approach. However, the tool is very flexible and modular and even those nations can benefit from adopting some of the components and integrating these with their existing approaches. If the initial effort can be made, then subsequent studies are made much easier since J-DARTS will be a repository for the required analysis and data. The next time around it is then a matter of updating unit data, scenarios and other inputs as required. Another benefit of J-DARTS is that it automatically provides an audit trail in that it is possible to trace back any result to the initial assumptions. This is something that is easily lost using spreadsheets, both because what is documented by spreadsheets is often only the *result* of the analysis, not the analysis itself, and because spreadsheets have a tendency to degrade over time (through constant minor modifications and subsequent problems with version control) and eventually discarded.